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Wake-up Scheduling for Event Monitoring in Wireless Sensor Networks

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ABSTRACT- *The attention is on critical event monitoring in wireless sensor networks (WSNs), where only a small number of packets need to be transmitted most of the time. When a critical event occurs, an alarm message should be broadcast to the entire network as soon as possible. To prolong the network lifetime, some Wakeup scheduling methods are always employed in WSNs, resulting in significant broadcasting delay, especially in large scale WSNs. A novel Wakeup scheduling method is proposed to reduce the delay of alarm broadcasting from any sensor node in WSNs. Specifically, two determined traffic paths are designed for the transmission of alarm message, and level-by-level offset based wake-up pattern according to the paths, respectively. When a critical event occurs, an alarm is quickly transmitted along one of the traffic paths to a center node, and then it is immediately broadcast by the center node along another path without collision. Therefore, two of the big contributions are that the broadcasting delay is independent of the density of nodes and its energy consumption is ultra low. Exactly, the upper bound of the broadcasting delay is only 3D + 2L, where D is the maximum hop of nodes to the center node, L is the length of Wakeup duty cycle, and the unit is the size of time slot.*

Keywords- *; WSN, Critical Event, Level-by-Level Offset, Wakeup Scheduling.*

I. INTRODUCTION

In operation-critical applications, such as battlefield reconnaissance, fire detection in forests, and gas monitoring in coal mines, the deployment of Wireless Sensor Networks is done in a wide range of areas, with a large number of sensor nodes detecting and reporting some information of urgencies to the end-users. As there may be no communication infrastructure, users are usually equipped with communicating devices to communicate with sensor nodes. When a critical event (e.g., intrusion or fire) occurs in the monitoring area and is detected by a sensor node, an alarm needs to be broadcast to the other nodes as soon as possible. Then, sensor nodes can warn users nearby to flee or take some response or activate defensive mechanism corresponding to the event.

The sensor nodes for event monitoring are expected to work for a long time without recharging their batteries, Wakeup scheduling method is always used during the monitoring process. Obviously, Wakeup scheduling could cause transmission delay because sender nodes should wait until receiver nodes are active and ready to receive the message. The delay could be significant as the network scale increases. Therefore, a delay-efficient Wakeup scheduling method needs to be designed to ensure low broadcasting delay from any node in the WSN.

Presently many Wakeup schedules for event monitoring have been designed. But, most of them focus on minimizing the energy consumption [1]. Actually, in the critical event monitoring, only a small number of packets need to be transmitted during most of the time. When a critical event is detected, the alarm packet should be broadcast to the entire network as soon as possible. Therefore, broadcasting delay is an important issue for the application of the critical event monitoring.

To minimize the broadcasting delay, it is needed to minimize the time wasted for waiting during the broadcasting. The ideal scenario is the destination nodes wake up immediately when the source nodes obtain the broadcasting packets. Here, the broadcasting delay should be minimum. Based on this idea, a level-by-level offset schedule is proposed. Hence, in this project to show if it is possible to achieve low transmission delay with the level-by-level offset schedule in multi-hop WSNs.

It is a challenge for us to apply the level-by-level offset to alarm broadcasting in the critical event monitoring. First, the order of nodes' wake-up should conform to the traffic direction [2]. If the traffic flow is in the reverse direction, the delay in each hop will be as large as the length of the whole duty cycle. Second, the level-by-level offset employed by the packet broadcasting could cause a serious collision. Finally, the transmission failure due to some unreliable wireless links may cause there transmission during the next duty cycle, which also results in large delay equaling the whole duty cycle.

A novel Wakeup scheduling method based on the level-by-level offset schedule to achieve low broadcasting delay in wireless sensor networks is designed. Two phases are set for the alarm broadcasting. Firstly, when a node detects a critical event, it originates an alarm message and quickly transmits it to a center node along a predetermined path with a level-by-level offset way. Then, the center node broadcasts the alarm message to the other nodes along another path also with a level-by-level offset way. Through designing a special wake-up pattern, the two possible traffics could be both carried by a node. To eliminate the collision in broadcasting, a colored connected dominant set in the WSN is established.

II. Traffic Paths

`First of all, a sensor node is initialized as the center node C. Then, the BFS tree is constructed which divides all nodes into layers H1, H2, H3; . . .;HD, where Hi is the node set with minimum hop i to c in the WSN. With the BFS tree, the uplink paths for nodes can be easily obtained [3].

To establish the second traffic path, we establish the CCDS in G with three steps:

1) Construct a maximum independent set (MIS) in G;
2) Select connector nodes to form a connected dominated set (CDS), and partition connector nodes and independent nodes in each layer into four disjoint sets.
3) Color the CDS to be CCDS

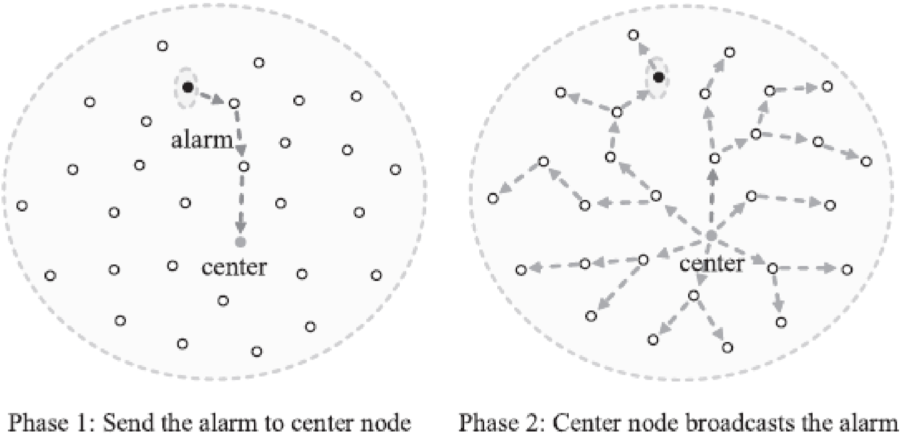

Figure 1. Traffic paths in WSN

III. Wakeup Pattern(Level by Level Offset

After all nodes get the traffic paths, sending channels and receiving channels with the BFS and CCDS, the proposed wake-up pattern is needed for sensor nodes to wake-up and receive alarm packet to achieve the minimum delay for both of the two traffic paths. There are two traffic paths for the alarm dissemination, and sensor nodes take two level-by-level offset schedules for the traffic paths. Fig. shows the two level-by-level offset schedules:

1) Sensor nodes on paths in the BFS wake up level-by-level according to their hop distances to the center node;
2) After the center node wakes up, the nodes in the CCDS will go on to wake up level-by-level according to their hop distances in the CCDS [4].

Hence, when an alarm packet is originated, it could be quickly forwarded to the center node along a path in the BFS, then, the center node immediately broadcasts it along the paths in the CCDS.

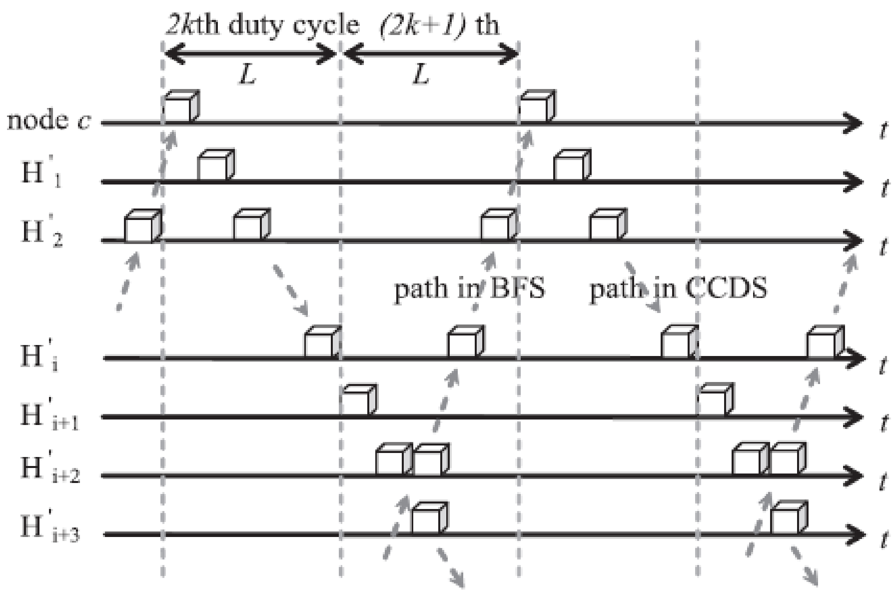

Figure 2. Wakeup pattern

Through designing a special wake-up pattern, the two possible traffics could be both carried by a node, and the node just needs to be awake for no more than ʈ time in each duty cycle, where Time slot is the minimum time needed by a node to transmit an alarm packet.

IV. PROBLEM DOMAIN

To enhance the network lifetime, some Wakeup scheduling methods are always employed in WSNs, resulting in significant broadcasting delay, especially in large scale WSNs. A novel Wakeup scheduling method is proposed to reduce the delay of alarm broadcasting from any sensor node in WSNs. Specifically, two determined traffic paths are designed for the transmission of alarm message, and level-by-level offset based wake-up pattern according to the paths given by BFS and CCDS.

It is assumed that a certain node, called as center node, in the network has obtained the network topology in the initialization (e.g., sink node). The center node computes the Wakeup scheduling according to the proposed scheduling scheme and broadcasts the scheduling to all the other Nodes.

V. PROPOSED METHODOLOGY

To reduce the broadcasting delay, the proposed scheduling method includes two phases:
1) Any node which detects a critical event sends an alarm packet to the center node along a predetermined path according to level-by-level offset schedule;
2) The center node broadcasts the alarm packet to the entire network also according to level-by level offset schedule. As an example Fig. illustrates these two phases of the processing.

Event detection: For the critical event monitoring in a WSN, sensor nodes are usually equipped with passive event detection capabilities that allow a node to detect an event even when its wireless communication module is in Wakeup mode. Upon the detection of an event by the sensor, the radio module of the sensor node is immediately woken up and is ready to send an alarm message.

Slot and duty cycle: Time is partitioned into timeslots. The length of each slot is about the minimum time needed by sensor nodes to transmit or receive a packet, which is denoted as Ʈ [5]. The length of each duty cycle is T = L *Ʈ, i.e., there are L slots in each duty cycle.

Network topology: For the sake of simplicity, it is assumed that the network topology is steady and denote it as a graph G.

Synchronization: Time of sensor nodes in the proposed scheme is assumed to be locally synchronous, which can be implemented and maintained with periodical beacon broadcasting from the center node.

Here $f(n_i)$ as the slot assignment function [6]. If $f(n_i) = s$, $s \epsilon \{0, \ldots\ldots, L-1\}$, it means that node n_i wakes up only at slot s to receive packets. Meanwhile, we define $F(n_i)$as the channel assignment function which assigns a frequency channel to node n_i.

The traffic paths from nodes to the center node is defined as uplink and define the traffic path from the center node to other nodes is defined as downlink, respectively. Each node needs to wake up properly for both of the two traffics. Therefore, the proposed scheduling scheme should contain two parts:
1) Establish the two traffic paths in the WSN;
2) Calculate the wake-up parameters (e.g., time slot and channel) for all nodes to handle all possible traffics.

To minimize the broadcast delay, a breadth first search tree is established for the uplink traffic and a colored connected dominant set for the downlink traffic, respectively.

To summarize, characteristics of the proposed Wakeup scheduling scheme are:

1. The upper bound of the broadcasting delay is3D + 2L, where D is the maximum hop of nodes to the center node, and L is the length of duty cycle, the unit is the size of time slot. As the delay is only a linear combination of hops and duty cycle, it could be very small even in large scale WSNs [7].
2. The broadcasting delay is independent of the length of the duty cycle, but it increases linearly with the number of the hops.
3. The broadcasting delay is independent of the density of nodes.
4. The energy consumption is very low as nodes wake up for only one slot in the duty cycle during the monitoring.

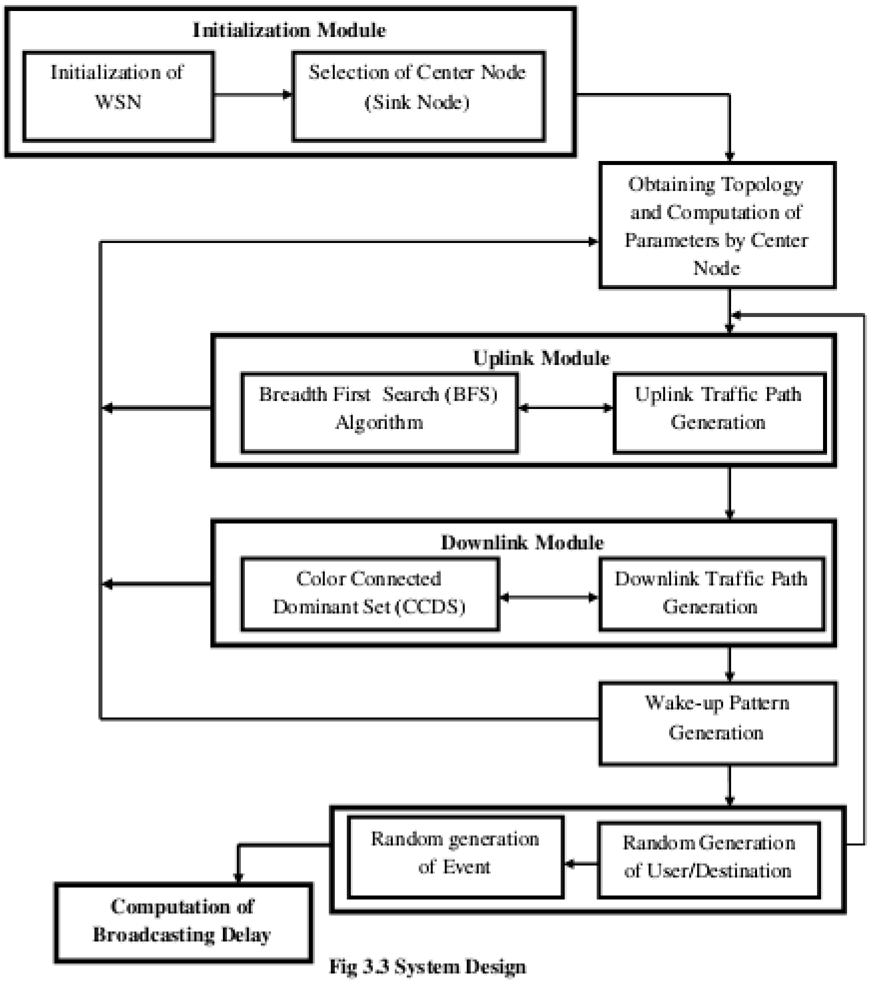

Fig 3.3 System Design

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Figure 3. Proposed Algorithm

VII. Computation of Broadcasting Delay:

The performance evaluation is the minimization of the broadcasting delay which is analysed by varying the time slot which for transmission of packets. The time slot is varied from 2ms to 10ms in order to evaluate the performance of the proposed scheduling algorithm.

The performance is evaluated keeping in consideration the various parameters. The parameters are as:

- Broadcasting delay in seconds(s).
- Time Slot (Ţ)
- Duty-cycle (T)
- Number of Experiments.
- Communication Probability between two nodes (p).

$$p = 1 - (d/20)^2$$

and

$$p > 50\%.$$

The performance is evaluated based on the parameters given above and also the simulation is done by deploying 225 nodes in area of 150*150 m^2.

- Firstly the experiments are performed by keeping the time-slot=2ms, the broadcasting delay is calculated for the eight experiments.
- Secondly the length of timeslot is increased to 20ms and the efficiency in minimizing the broadcasting delay is observed.

There are other parameters on which the broadcasting delay is dependent such as [8]:

- Baud Rate.
- Bandwidth of the frequency Channel.
- Number of Alarm packets transmitted.

VIII. CONCLUSION AND FUTURE WORK

In this paper a Wakeup scheduling scheme for critical event monitoring is proposed in WSNs. The proposed Wakeup Scheduling scheme decreases the delay of alarm broadcasting from any node to center node and then center node to all nodes in WSN. The proposed algorithm when applied to a wireless sensor network minimizes the broadcasting delay of the transmission of alarm packets in the network from the source node to destination node. The center node broadcasts the alarm packets with minimum delay to all nodes in the network using level-by-level. The efficiency of the proposed Wakeup scheduling scheme is higher than the previous algorithms. The upper bound of the delay is 3D + 2L, which is just a linear combination of hops and duty cycle. The alarm broadcasting delay is independent of the density of nodes in WSN.

Link stability is one of the most important factors that affects the quality of service and also accounts for finding a better route in terms of network stability. When any link corresponding to a path breaks, the path has to be either repaired or an alternative path has to be found out. Re-routing results in energy consumption and delay in data transfer. So the future enhancement in the algorithm is to incorporate the factor of maintaining the link stability.

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